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# HYDRAULIC COMPACTION DEVICE FOR MAKING SOIL CORES

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## Abstract

It is now well established that soil compaction of agricultural land used for crop production is a major problem. For basic laboratory investigations of soil compaction, it is important that multiple soil cores of varying bulk densities be reproduced within statistically acceptable ranges. A device was designed, constructed, and tested to consistently compact soil cores of varying dimensions and bulk densities. The device uses two opposing hydraulic cylinders to evenly compress soil samples. The compactor is designed to generate compacted cylinders varying from 50 to 100 mm in diameter and 25 to 150 mm in length. Bulk density values for 10 replications of a 150-mm soil cylinder with a 50-mm diameter did not vary significantly when compacted under a single pressure. Pressures of 0.35, 1.04, and 2.07 MPa produced cores having bulk densities of 1.66, 1.76, and 1.86 g cm$^{-3}$, respectively. Approximately 10 cylinders per hour can be prepared with this device.


Soil compaction has been identified as a significant production problem for agriculture today (Nelson et al., 1975; Bakken et al., 1987; NeSmith et al., 1987; Torbet and Reeves, 1991). There is a need for fundamental research to understand the effects that soil compaction has on soil and plant processes (Asady et al., 1985). A variety of experiments designed to understand the effects of soil compaction on both plant and soil processes are dependent on the ability to generate consistently compacted soil cores. For this type of research, it is essential that multiple soil cores be prepared that have bulk density values within a narrow range.

Soil compaction affects a variety of plant and soil processes deserving of scientific examination. The dimension of soil cores used in a particular investigation will probably vary depending on specific needs and the objectives of a particular study. For example, experimentation involving plants or seeds will need large cores to accommodate plant growth, while much smaller cores will need to be employed in incubation studies to properly utilize laboratory equipment. Regardless of the dimensions required, soil cores of consistent soil bulk densities will be needed to investigate the effects of soil compaction. The following is a description of a soil compaction device designed to rapidly compact soil cores of varying lengths, diameters, and bulk densities with consistent precision.

## Materials and Methods

The soil compactor (Fig. 1 and 2) was built using two Prince Hydraulic Model SAE 9408 hydraulic cylinders (Prince Mfg. Co., Sioux City, IA[1]; Fig. 1-D and 2-D) mounted on a reinforced steel table (Fig. 1-A). The hydraulic cylinders have a 101.6 by 203 mm bore and stroke capable of applying equivalent force to each end of the soil test cylinder concurrently. A two-speed, hand-operated hydrostatic pump (Prince Hydraulic Model PMNP 10; Fig. 1-H and 2-H) is used to generate hydraulic pressure for the two cylinders. A four-way directional control valve (Model 23THX, Williams Machine & Tool Co., Omaha, NE; Fig. 2-G) and volumetric flow divider (Model 2V13-3-10S, Fluid Controls Inc., Mentor, OH; Fig. 2-F) were used to equally distribute pressure to the two cylinders, thus resulting in a more uniformly compressed soil core. In use, a soil sample is placed in a PVC sleeve and placed between the two rams of the system. The rams operate simultaneously and compress the sample into a uniform cylinder. Low-pressue gauges (0–4.14 MPa; Fig. 2-J) are mounted on each hydraulic cylinder to monitor the pressure generated within each cylinder.

Centered between the two hydraulic cylinders is an enclosure (Fig. 1-K, measuring 134.8 mm o.d. by 115 mm i.d. by 406.4 mm length) that is mounted onto the table to hold soil test cylinders. This enclosure is split in half horizontally and hinged at the back so that soil test core cylinders can be positioned and then locked into place for soil compression. Smaller soil cores can be used in this device by placing them inside a larger cylinder called a collet (Fig. 1-C and 2-C). The test cylinders used were PVC (schedule 40 PVC) tubes measuring 60 mm o.d. by 50 mm i.d. by 150 mm length. These cylinders were cut into three 50-mm sections and held together with tape. The collet was made from a solid aluminum rod of 101.6-mm diameter and 393.7-mm length that was bored out to an inside diameter of 63.5 mm. The collet was split in half to facilitate positioning of the small soil test cylinders inside it. The two halves were held together by two 114 mm o.d. by 106 mm i.d. by 37 mm length PVC rings positioned 50.8 mm from each end of the collet. The collet containing the small test cylinder was then located in the hinged enclosure for soil compression. Heads for the hydraulic cylinder (Fig. 1-B) were machined to match the desired test cylinder diameter and placed on the ends of each cylinder (50 mm for this study). The parts used in the construction of this device (approximately $500.00) are readily available and could be easily assembled by a competent shop person.

To test the performance and reliability of this device, soil test cylinders containing a Cahaba fine sandy loam (fine-loamy, siliceous, thermic Typic Hapludult) were compressed at three pressures: 0.35, 1.04, and 2.07 MPa. Ten replications of each pressure were made at a soil water

Table 1. Soil bulk density measurements of three sections† of a 50-mm-diam. soil core following compression with a soil compactor.

| Pressure‡ | Bulk density | | | Mean |
|---|---|---|---|---|
| | Outside | Inside | Outside | |
| MPa | | g cm$^{-3}$ | | |
| 0.35 | 1.68 | 1.62 | 1.68 | 1.66 a§ |
| 1.04 | 1.76 | 1.73 | 1.79 | 1.76 b |
| 2.07 | 1.88 | 1.82 | 1.78 | 1.86 c |
| Mean | 1.78 a | 1.72 b | 1.78 a | |

† Ends and center sections with 50-mm diameter and 50-mm length removed from a 150-mm-long soil core.
‡ Pressure applied to soil cores at the hydraulic cylinder.
§ Means followed by the same letter within a column or within a row do not differ significantly (0.01 level, CV = 1.77).

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[1] Trade names and products are mentioned soley for information. No endorsement by the USDA is implied.

Abbreviations: PVC, polyvinyl chloride; ANOVA, analysis of variance; CV, coefficient of variation.

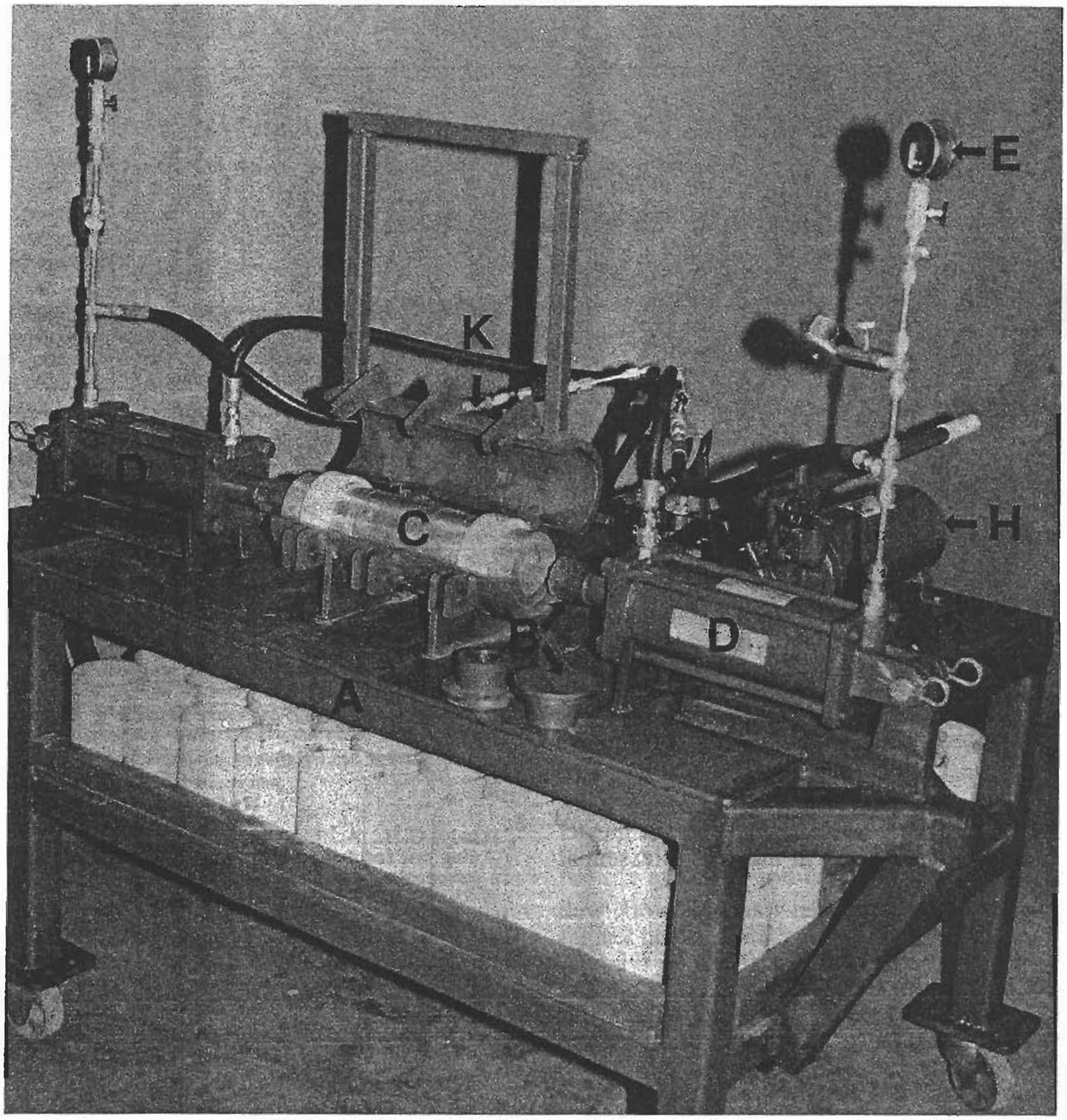


**Fig. 1. Photograph of a hydraulic soil compactor device for compacting soil cores for soil compaction studies. A = table top, B = piston heads (varying sizes), C = collet, D = hydraulic cylinders, E = pressure gauges (0–4.14 MPa), H = hydrostatic pump (20.7 MPa), K = hinged enclosure.**

content of 77 g $kg^{-1}$. The hydraulic pressure reported is for the pressure generated at the hydraulic cylinder. The resulting soil bulk density for a given pressure will depend on the soil series, soil water content, and the diameter of the core being compressed. Each compressed cylinder was divided into three 50-mm increments and soil bulk density determinations were made for each increment. Soil cores were divided using a sharpened hacksaw blade. Soil was oven dried at 105 °C for 36 h. Bulk density calculations were made from the oven-dry weight of the soil divided by the volume of the core section. Statistical analysis of the bulk densities generated in the two ends and the center of the core were made with ANOVA, with means separated by Fisher's protected least significant difference test.

## Results and Discussion

The soil compactor produced soil cores with mean bulk densities of 1.66, 1.76, and 1.86 g $cm^{-3}$ for the 0.35, 1.04, and 2.07 MPa pressures, respectively (Table 1). No significant differences (0.01 level) was found among soil cores compressed to the same level of hydraulic pressure (CV = 1.77). In addition, no significant differences (0.01 level) in the soil bulk density measurements were found for either end of the soil cores at any of the pressure levels (Table 1). This indicated that the soil cores that were compacted under a single pressure were statistically identical. However, a significant reduction of approximately 0.06 g $cm^{-3}$ resulted from the center section of the cores, compared with the two outside sections. This is a result of friction along the walls of the cylinder as it moves away from the point of applied pressure. This indicated that the use of two hydraulic cylinders compressing from either side of a soil core is helpful in obtaining an evenly distributed soil density inside the

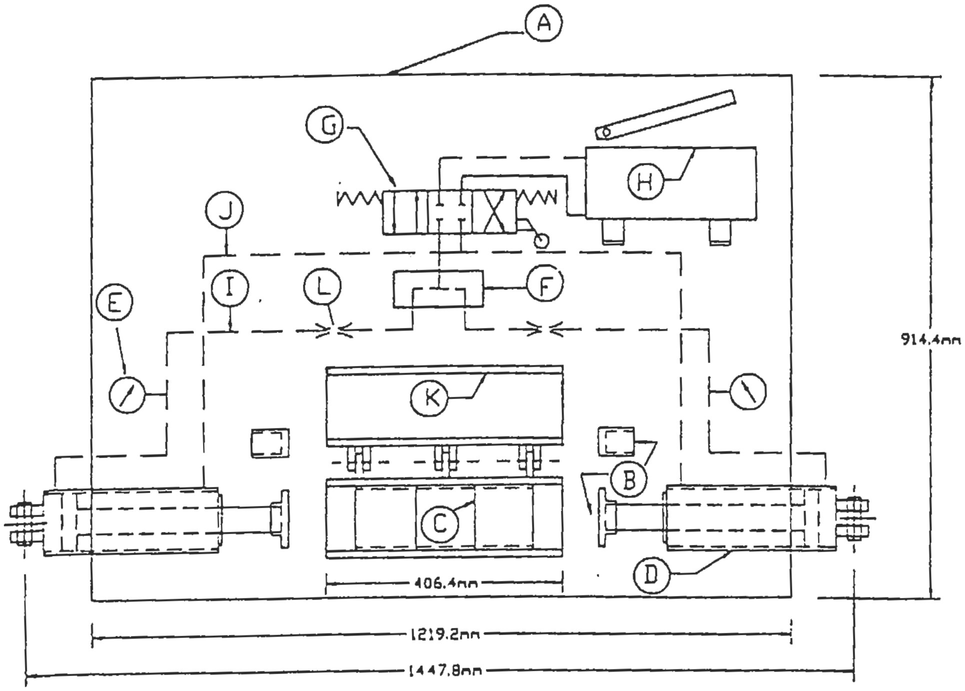


Fig. 2. Schematic of a hydraulic soil compactor device for compacting soil cores for soil compaction studies. A = table top, B = piston heads (varying sizes), C = collet, D = hydraulic cylinders, E = pressure gauges (0–4.14 MPa), F = volumetric flow divider, G = directional control valve, H = hydrostatic pump (20.7 MPa), I = high-pressure lines, J = low-pressure lines, K = hinged enclosure, L = back-pressure valves.

core. Caution should therefore be used when compressing soil cores having lengths of 150 mm or greater if an even distribution of soil in the core is essential to the study.

This soil compactor has been found to work well in generating soil cores of varying diameters and lengths for experimental purposes. It was found in this and other studies that approximately 10 cores per hour can be compressed by this device. The results from this study show that statistically identical soil cores could be generated in this manner, thus reducing experimental variability for soil compaction research.

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